Journal of Radiation Researches, vol.5, No.2, 2018, Baku

UDC: 621.315.592

IMPACT OF γ-RADIATION ON ELECTRICAL PROPERTIES OF EPITAXIAL FILMS OF $Pb_{1-x}Mn_xSe$

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Abstract: The electrical properties of epitaxial film of p-type $Pb_{1-x}Mn_xSe$ (x=0.01) obtained from molecular cluster on glass substrate by the precipitation method and the results of impact of gamma radiation on these properties have been studied in the presented work. It has been established that, the defects generated as a result of impact of gamma rays are acceptor type and therefore, the conductivity increases after radiation.

Keywords: epitaxial film, volt-amperage characteristics, gamma rays, radiation defects

1. Introduction

Obtaining semiconductor materials with new properties, studying their physical properties and developing the methods of purposeful controlling these properties are one of the important issues of modern material science. One of the materials that are of special scientific and practical importance is narrowband $Pb_{1-x}Mn_xSe$ solid solutions, which are included in $A^{IV}B^{VI}$ type semiconductor group. There are several studies on the obtaining of epitaxial films of $Pb_{1-x}Mn_xSe$ and investigating their electrophysical properties in scientific literature [1, 2]. These studies are mainly devoted to the improvement of obtaining technology of films. It is known that the initial defects play primary role in the controlling physical properties in such complex-compound films. It is possible to control physical properties by changing the concentration of these defects by certain methods (alloying, thermal annealing, irradiation with radiation rays, etc.). There is almost no information in the scientific literature on controlling their concentration by alloying and external influences, especially by the effects of radiation rays. The electrical properties of epitaxial film of p-type $Pb_{1-x}Mn_xSe$ (x=0.01) obtained from molecular cluster on glass substrate by the precipitation method and the results of impact of gamma radiation on these properties have been studied in the presented work. The samples have p-type conductivity. The crystalline excellence of the samples has been studied by electronographic, radiographic methods. The thickness of the obtained film was 3mkm. Silver paste has been used as a contact material. The distance between the contacts was 0.6mm. Silver contacts dried at room temperature for 24 hours after applying. It has been determined by the volt-ampere characteristics (VAC) that the contacts are Ohmic. The samples have been irradiated by γ-rays which are irradiated by ^{60}Co isotope source at 290 K. The energy of γ-rays was 1.17-1.33 MeV.

2. Experimental part

Investigation of the dependence of volt-ampere characteristics (VAC), as well as electroconductivity on temperature, electric field intensity allow getting information on electrical properties of semiconductor materials, parameters of local levels in the band gap of these materials, etc.

The electrical properties of the samples have been investigated before and after radiation in order to study the effects of the electrical properties of the epitaxial films of $Pb_{1-x}Mn_xSe$ (x=0,01) obtained from molecular cluster on the glass substrate by the precipitation method and the effects of gamma rays on these properties.

Figure 1 depicts the dependence ($lgI \sim \frac{10^3}{T}$ dependence) graph of the current intensity on inverse values of temperature in different values of tension (5V, 10V, 20V, 30V and 40V). From this graph, it has been established that there are three local levels with the activation energy ΔE_1= 0.09eV, ΔE_2= 0.17eV and ΔE_3= 0.196eV in the dependence $lgI \sim \frac{10^3}{T}$ at U=5V. The value of activation energy varies slightly, as the tension increases, and the graph consists of a straight line with activation energy ΔE = 0.161eV in $lgI \sim \frac{10^3}{T}$ dependence at U = 40V.

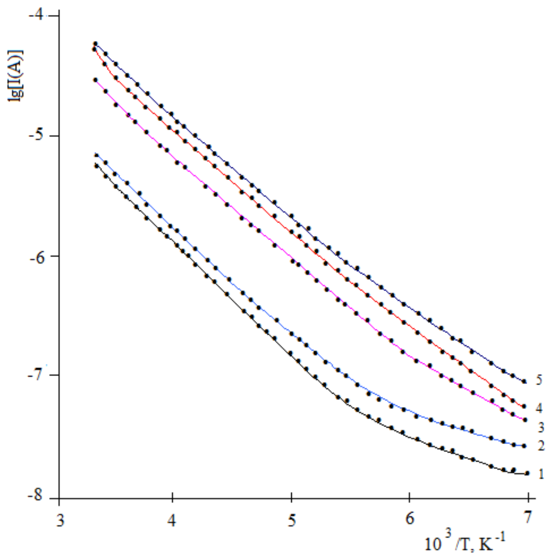

Figure 1. Dependence ($lgI \sim \frac{10^3}{T}$) graph of current intensity on temperature at different intensities for epitaxial film of $Pb_{1-x}Mn_xSe$ (p-type, x=0.01). 1- 5V, 2- 10V, 3- 20V, 4- 30V, 5- 40V

Figure 2 depicts the VACs of the sample initial (curves 1 and 2) and irradiated (curves 3, 4, 5 and 6) with gamma quanta at 10 and 20 kGy doses, at 300K and 125K temperatures. As it can be seen from the graph, the VAC (curve 1) of the initial sample at 300K temperature consisted of linear (ohmic) part up to E=$1.67 \cdot 10^3$ V/m value of intensity of electric field. But in the values of E>$1.67 \cdot 10^3$ V/m of intensity of electric field (up to the value of $1.87 \cdot 10^5$ V/m) it consists of a part deviated from linearity ($J \sim U^r$, r=1.2). It is seen from VAC (curve 2) obtained for initial sample at 125K temperature that, VAC consists of a part higher (r=1.28) than linearity up to the $1.8 \cdot 10^5 \frac{V}{m}$ value of intensity of electrical field at low temperature. The observation of slightly deviation from Ohmic law in the high range ($1.67 \cdot 10^3$-$1.87 \cdot 10^5$ V/m) of intensity of electrical field in the VAC obtained for $Pb_{1-x}Mn_xSe$ (x=0.01) epitaxial film shows that, the concentration of free charge carriers in balance state has slightly changed. And it shows the slightly change of a balance between the capture of charge carriers by the traps having low activation energy in band gap and the release from traps thermally. In this case, injected charge carriers slightly change the concentration of charge carriers in a balance state. The balance between free and captured charge carriers can only vary by injection in the not-so-high values of intensity of electrical field. So, the increase in the concentration of free charge carriers in the part higher than Ohmic part in VAC obtained for epitaxial film $Pb_{1-x}Mn_xSe$ is due to injection.

At the temperature 300K, the VAC (curve 3) irradiated with gamma rays at 10kGy dose differs slightly from the VAC of initial (unirradiated) sample at the same temperature. It is interesting that in this case, the value of current intensity up to 1.2V tension is low than the value of current intensity of the initial state; but after 1.2 V value of tension, the value of current intensity after the irradiation is higher than the initial state and as the intensity of the field increases, the difference between initial and irradiated current intensities at the same tension increases.

But at the temperature of 125K, the current intensity at the same tension is 4 times higher in the samples irradiated (curve 4) with γ-rays in 10kGy dose compared with initial state and the graph is practically parallel to the previous one. It is seen from the graph obtained after irradiation in 20 kGy dose that, the conductivity slightly varies with the further increase in dose.

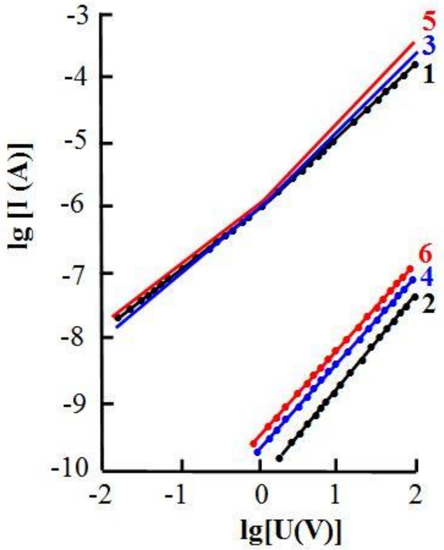

Fig. 2. VAC of epitaxial film of $Pb_{1-x}Mn_xSe$ (p-type, x = 0.01) initial (1 and 2) and irradiated with γ-rays in different doses, in the dark at different temperatures. 1,3,5 - 300K, 2,4,6- 125K. 3,4-10 kGy, 5,6 - 20 kGy.

The study of temperature dependence (lgI~$\frac{10^3}{T}$ dependence) of the current intensity in the dark after 10kQr dose irradiation with gamma rays showed that the electrical conductivity in the dark increases compared with the state before irradiation at all tensions investigated in the temperature range of 125-300K after irradiation. Temperature dependence of current intensity in the dark has been given as an example in figure 3 for initial and irradiated samples at 5V and 40V tensions.

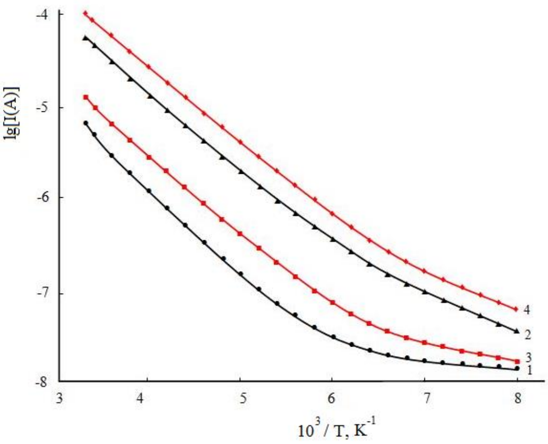

Fig. 3. Temperature dependence of current intensity ($lgI \sim \frac{10^3}{T}$) at different tensions in the dark for epitaxial film $Pb_{1-x}Mn_xSe$ (p-type, x=0.01) initial (1 and 2) and irradiated with γ-rays at 10kGy doses (3 and 4). 1,3- U=5 V, 2.4- U=40 V.

Using the information given in [4] we found that the Compton scattering occurs due to the interaction of γ-quanta with the energy 1.17-1.33 MeV with electrons in the sub-layers of the atoms located in the crystal lattice nodes while passing through the epitaxial films of $Pb_{1-x}Mn_xSe$. As a result of Compton scattering, electrons get some kinetic energy. The maximum kinetic energy given to the electrons by γ-quanta was average ≈ 0.8 MeV. These electrons give the atoms in the crystal lattice nodes a certain amount of energy while interacting with them. The maximum energy that they can obtain as a result of interaction of atoms with fast electrons in epitaxial films of $Pb_{1-x}Mn_xSe$ has been calculated by the formula given in [5]. The maximal energy was E_{max}=41 eV for Se atoms, E_{max}=59 eV for Mn atoms, and E_{max}=16 eV for Pb atoms. The minimal energy (threshold energy) required to transfer the atoms from the crystal lattice node to the internodal phase was calculated by the Bayerline formula. The increase in conductivity in the p-type $Pb_{1-x}Mn_xSe$ samples can be due to the formation of Se vacancies after γ-quanta radiation. As it is known, the formation of halogen vacancies in such compounds leads to an increase in the positive charge state. Therefore, the minimal energy for the transfer of Se atoms to internodal phase in $Pb_{1-x}Mn_xSe$ compound has been calculated. The value of this energy (threshold energy) was 14.2 eV and 15.1 eV. As it turns out, the energy given by electrons to the Se atom is enough to pass to the internodal phase, and the point defects consist mainly of Se vacancies.

3. Conclusion

From the experimental facts, the result is that, as the epitaxial films of $Pb_{1-x}Mn_xSe$ are narrowband semiconductor, the increase of concentration of charge carriers in $E=1.67 \cdot 10^3$-$1.87 \cdot 10^5$ value of electrical field at room temperature is due to the injection from contacts. The minimal energies (threshold energy) required for the transfer of atoms in composition from lattice node to internodal phase and the kinetic energies that can be given to atoms in composition by γ-quanta have been calculated. It has been established that the defects formed as a result of γ-quanta radiation is simple Frenkel defects, which consists mainly of Se atoms that have passed into the internodal phase and their vacancies. After radiation, the physical properties of epitaxial films of $Pb_{1-x}Mn_xSe$ at room temperature change slightly, but the difference at low temperatures is relatively large. This is due to the fact that the $Pb_{1-x}Mn_xSe$ epitaxial layer has a narrowband semiconductor.

References

1. I.R. Nuriyev, M.B. Hajiyev, R.M. Sadigov. Growth and structure of epitaxial films $Pb_{1-x}Mn_xSe$ (Ga) // Crystallography, 2009, 54**(**2), p.331-333
2. I.R. Nuriyev, M.B. Hajiyev, R.M. Sadigov, A.M. Nazarov, Structure and photo-electric properties of epitaxial films $Pb_{1-x}Mn_xSe$ // Applied Physics, 2007, (2), p. 132-135
3. Y.I. Ravich, B.A. Efimova, I.A. Smirnov. Methods for studying semiconductors in application to lead chalcogenides PbTe, PbSe, PbS. M.: Nauka, 1985, p. 383.
4. V.V. Yemchev, T.V. Mashovets. Impurities and point defects in semiconductors. Ed. "Radio and communication", Moscow, 1981, 248.
5. V.S. Vavilov, N.A. Ukhin. Radiation effects in semiconductors and semiconductor devices. "Atomizdat", Moscow, 1969.

$Pb_{1-x}Mn_xSe$ EPİTAKSİAL TƏBƏQƏLƏRİNİN ELEKTRİK XASSƏLƏRİNƏ γ-ŞÜALANMANIN TƏSİRİ

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Xülasə: Təqdim olunan işdə molekulyar dəstədən kondensasiya üsulu ilə şüşə altlıq üzərində alınmış p-tip $Pb_{1-x}Mn_xSe$ (x=0,01) epitaksial təbəqəsinin elektrik xassələri və bu xassələrə qamma şüaların təsirinin nəticələri tədqiq edilmişdir. Müəyyən edilmişdir ki, qamma şüaların təsiri nəticəsində yaranan defektlər akseptor tiplidir və ona görə də şüalanmadan sonra keçiricilik artır.

Açar sözlər: epitaksial təbəqə, volt-amper xarakteristikası, qamma şüalar, radiasiya defektləri.

ВЛИЯНИЕ γ-ИЗЛУЧЕНИЯ НА ЭЛЕКТРИЧЕСКИЕ СВОЙСТВА ЭПИТАКСИАЛЬНЫХ ПЛЕНОК $Pb_{1-x}Mn_xSe$

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Резюме: В данной работе были исследованы электрические свойства эпитаксиальных пленок р-типа $Pb_{1-x}Mn_xSe$ (x = 0,01) полученных на стекленной подложке из молекулярного пучка по методу конденсации и результатами действия гамма-излучения на эти свойства. Установлено, что дефекты, обусловленные действием гамма-излучения, имеют акцепторный тип и поэтому электропроводность возрастает после облучения.

Ключевые слова: эпитаксиальные пленки, вольт-амперные характеристики, гамма излучения, радиационные дефекты.